PATENT SPECIFICATION 1,103,130

DRAWINGS ATTACHED.

1,103,130

Date of Application and filing Complete Specification: 8 July, 1966. No. 30854/66.

Application made in United States of America (No. 483,176) on 27 Aug., 1965.

Complete Specification Published: 14 Feb., 1968.



Index at Acceptance:—**B1** B1; **F4** P(11, 13).

Int. Cl.:—**B 01 d 5/00.**

COMPLETE SPECIFICATION.

# Separation of Components of a Predominantly Gaseous Stream.

We, ESSO PRODUCTION RESEARCH COMPANY, a Corporation duly organized and existing under the laws of the State of Delaware, United States of America, of Houston, Texas, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is related generally to a method for the separation of components of multicomponent gaseous streams, and more particularly to a technique for carrying out such separation, which does not involve the use of heavy, expensive auxiliary equipment.

Considerable economic incentive exists for separating those components of a gaseous stream, such as a natural gas stream, which are normally liquid or which have relatively high condensation temperatures e.g. propane, butane, pentane, propylene, ethylene, acetylene and nitrous oxide, from gases such as methane, oxygen, hydrogen and nitrogen which have relatively low condensation temperatures. Large, expensive separation plants have been built at various locations for the purpose of separating such products of gas wells. The gaseous components having low condensation temperatures either are transmitted to a pipeline or are returned to the reservoir from which they came, and the remaining components are sold or otherwise utilized. Separating plants used heretofore have required a substantial economic investment and, manifestly, have been economically feasible only when the products of gas wells are relatively rich in components having high condensation temperatures. There exists a need, therefore, for apparatus which would substantially reduce the economic investment required for such separation.

In accordance with the teachings of the present invention, a predominantly gaseous stream is accelerated to supersonic velocity, as by expanding it substantially isentropically with high adiabatic efficiency. (By a "predominantly gaseous stream" is meant a completely gaseous stream as well as a stream having a minor amount of liquid or solid content; for example, a gas stream having 0-10% liquid and/or solid content.) The supersonic stream is directed along a curved porous barrier and is thereafter decelerated to subsonic velocity. When the gas is accelerated, a broad band of sound waves can be produced which coagulates the droplets resulting from the tremendous temperature drop attendant upon acceleration to supersonic velocities. The droplets pass through the porous barrier and fill the pore spaces thereof so that gas is partially excluded from passing through the barrier. By regulating the back pressure on the other side of the barrier, a product which is greatly enriched in components having high condensation temperatures is obtained.

When it is desired to separate components of predominantly gaseous streams having a very lean mixture of heavy hydrocarbons and liquids relative to the methane content, after the stream is accelerated to supersonic speed it is subjected to an intense electric field, preferably at least 50 kv per centimeter. It has been found that such an electric field in combination with the intense sound produced by acceleration of the gas to supersonic speed functions to enhance the coagulation of the liquid droplets produced when the accelerated gas stream cools to a temperature lower than the condensation temperature of certain components

[F ]

thereof. A whistle or other sound force may be used to produce frequencies particularly adapted to coagulate droplets of particular sizes when such frequencies happen to be of low amplitude in the sound spectrum generated by accelerating the gases to supersonic velocity.

In the accompanying drawings, Fig. 1 is a side view, partially in cross section, of an embodiment of the invention; Fig. 2 is a sectional view taken along section 2-2 of Fig. 1; Fig. 3 is a sectional view taken along section 3-3 of Fig. 1; Fig. 4 is a fragmentary view of a portion of the apparatus of Fig. 1 illustrating a modification of the invention; and Fig. 5 is a schematic flow diagram illustrating a complete separation system in accordance with the invention.

Reference is now made to the embodiment of the invention illustrated in Fig. 1. A nozzle housing 2 is illustrated as comprising bolted-together sections 5 and 7. Nozzle housing section 5 is connected to a pipe 1 leading from a source of high pressure gas, as will be described with respect to Fig. 5. The pipe discharges into a cavity 3 defined by the housing sections 5 and 7. At the outlet from the cavity 3 there is positioned a replaceable nozzle 9. The function of the nozzle 9 is to expand gas flowing therethrough from the high pressure source pipe 1 and cavity 3 substantially isentropically with high adiabatic efficiency. The design of nozzles of this type is well known to the art. By substantially isentropically expanding the gas, the temperature thereof can be reduced to below the condensation temperature of the desired constituents thereof. For example, assuming that the temperature of the entering gaseous stream is 100°F, the temperature of the gas can be reduced easily to between −40°F and −80°F.

Abutting against the outlet of nozzle 9 is a droplet-coalescing section 11. The housing for the droplet-coalescing section is held between a flange 23 at the outlet end of the nozzle housing section 7 and a flange 25 at the inlet end of the gas-liquid separating assembly 31, to be described below. A plurality of tie rods 21 are bolted between the flanges 23 and 25 to hold the droplet-coalescing section in place. The droplet-coalescing section defines a divergent channel 26 for maintaining the gas at high velocity. The design of such a divergent channel can be found in a number of publications. The length of the droplet-coalescing section 11 may be between one and two feet. This length has been found to be sufficient to permit droplets to coalesce to a reasonable size, as will be described below.

In Fig. 2 a cross-sectional view of the droplet-coalescing section is shown; it can be seen that the section can be formed of four blocks bolted together holding high voltage electrodes 28 in place, which electrodes define the side walls of the divergent channel 26. The blocks holding the electrodes in place are of an insulating material such as ceramic or plastic. The function of the electrodes is to place a very high electric field across the channel 26 so as to aid in the coalescing of liquid droplets in the flow stream. Preferably, the intensity of the electric field should be not lower than 50 kv per centimeter. A preferable range for the electric field is between 50 and 300 kv per centimeter. Leads 27 for connection to a high voltage source extend through the side walls of the insulating material.

Connected to the outlet end of the droplet-coalescing section 11 is a gas liquid separating assembly 31. This assembly includes a curved porous wall 33, which may be formed of a porous stainless steel such as is manufactured by the Pall Micrometallic Corporation of New York City, and a housing therefore which may comprise a plurality of bolted-together sections 36, 38, and 40, (Fig. 3). which form a curved channel or passageway 37, one wall of which is the porous wall mentioned above. The passageway receives the gas from the channel 26 in the droplet-coalescing section 11 and is divergent in design. The porous wall 33 is held in place by a wall retainer 39 which is clamped or bolted to the plate 38. A plurality of out-flow channels 35A, 35B, ... and 35F are shown for the purpose of receiving liquid droplets flowing through the porous wall as a result of pressure differential thereacross. Fittings 59 couple each of the out-flow channels to lines leading to a plurality of back pressure regulators and a header, as will be described with respect to Fig. 5.

Rather than using a plurality of metal sections bolted together as shown in Fig. 3, the channels or passageways illustrated in Fig. 1 (other than the porous metal wall 33) can be machined in a single metal plate, and a cover plate can be bolted thereto.

A bolting flange 45 is provided at the outlet end of the gas-liquid separating assembly 31 for connection to an outlet nozzle assembly 49 through a flange 47 thereon. An outlet nozzle 51 in the outlet nozzle housing assembly is for the purpose of decreasing the velocity of the gas stream and thereby compressing the gaseous stream with high adiabatic efficiency. Such a nozzle is commonly called a diffusor. The gas then discharges through a discharge pipe 55 to other components of the system, as will be described below with respect to Fig. 5.

With reference now to Fig. 5, the apparatus described above with respect to

Fig. 1 is illustrated in a complete system for separating components of a gaseous stream. A line 95 from a gas well is coupled to the inlet pipe 1 of the apparatus of Fig. 1 through heat exchangers 87, 85, and 86, which are connected together in the order named by lines 89 and 84. A high voltage source 67 is connected to electrodes 28; however, this source is not absolutely necessary except when extremely lean gas mixtures are to be separated, as will be described below. The outlet pipe 55 from the separator assembly 31 is coupled by line 91 to heat exchanger 87, and gas therefrom is conducted to a pipeline or utilizing location by line 91. The lines 57A, 57B, 57C ...and 57F from out-flow channels 35A, 35B... and 35F are connected to a liquid header 69 through back pressure regulators 58A, 58B ... and 58F, respectively. The function of the back pressure regulator is to keep a relatively constant pressure drop across the porous wall 33, as will be described below. The liquid collected in header 69 is in turn conducted to a back pressure regulator 73 through line 71. The function of back pressure regulator 73 is to ensure that flow will be maintained through the liquid header 69. The back pressure regulator 73 will be set to a pressure somewhat lower than the pressure of back pressure regulator 58F. The output from back pressure regulator 73 is connected by line 75 to a multistage stabilizer 79, the function of which is to separate out any normally gaseous low condensation temperature constituents such as methane and ethane in the liquid product to permit such gas to be slowly removed so that there is no carry-over of liquid into gas outlet line 83. The gas from gas outlet line 83 is passed through heat exchanger 85 and thence to a product line 93. The liquid from the separator 79 is passed through line 81 to a heat exchanger 86 and then to a liquid product line 94.

The operation of the apparatus described above with respect to Figs. 1, 2, 3 and 5 is as follows. Gas from the well connected to line 95 will flow through the heat exchangers 87, 85, and 86 to the inlet line 1 of the seperator assembly. When the gas flows through the expansion nozzle 9 there will be produced noise of very broad spectrum and high frequency content. This noise will be quite intense so that the liquid droplets produced by the temperature drop that the gas suffers when it is expanded by the nozzle will be vibrated in such a manner as it flows through the droplet-coalescing section 11 that the droplets will coalesce and grow to substantial size. The gas will be flowing at the rate of about 1800 feet per second, and the condensed liquid coalesces to form droplets at the outlet of the coalescing section which are large enough to be ejected from the stream when the direction of the stream is changed.

As is evident, the droplets at the outlet of the droplet-coalescing section 11 are much heavier than the molecules of gas in the flow stream. Therefore, as the droplets travel around the bend defined by gas-liquid separating assembly 31, they will be thrown against the porous wall 33. Very quickly the pores of the wall will become about 90% saturated with liquid so that very little gas can pass therethrough. The gas will continue to flow through the divergent channel or passageway 37 and will be compressed by nozzle 51 and pass on to line 55. Inasmuch as there will be some decrease in pressure of the gas by flowing through the separator assembly, the gas in line 55 will be cooler than the gas passing through line 1 so that it is desirable to pass this gas through the heat exchanger 87 to effect some cooling of the gas entering the heat exchanger from line 95.

The liquid passing through the porous wall 33 is collected in the out-flow channels 35A to 35F and passes through lines 57A to 57F and back pressure regulators 58A to 58F to header 69. The back pressure regulators 58A to 58F are set to effect a pressure drop across the porous wall 33 which is adequate to remove the material collecting in the porous wall. This pressure depends on the permeability of the porous wall and the amount of liquid collecting on the wall, but will usually be from 5 to 50 psi. Inasmuch as there will be a pressure drop in the gas flowing through channel 37, the back pressure regulators 58A to 58F are set at progressively lower back pressures to maintain the drop across the porous wall substantially uniform and to prevent backflow through the wall. The liquid collected in header 69 is passed through a back pressure regulator 73 and separator 79. The gas product from separator 79 is used to cool the outlet gas from separator 87 inasmuch as this gas in line 83 is quite cold. Furthermore, the liquid product from separator 79 is fed through line 81 to heat exchanger 86 to further cool the gas which leaves heat exchanger 85 so that the thermodynamic efficiency of the system can be maximized.

When extremely lean mixtures are fed to the system from line 95, it is advantageous to place a very high electric potential between electrodes 28. This potential may be from either an alternating or a direct current source. It has been found that when such a field is placed across the assembly, the droplets tend to coalesce much more

rapidly than when sound alone is used as the coalescing force. Increasing the intensity of the field will cause faster coalescence of droplets, but the field strength must not exceed the electrical breakdown point of gas between the electrodes. Breakdown point is the electric field strength at which an electric arc would form in the gas stream. Breakdown point of a gas depends on gas pressure.

The curvature of the channel or passageway 37 is important. Preferably, the length of the channel or passageway 37 is between 3 and 15 feet, and the radius of curvature is between 2 and 5 feet. The total bend may be between 90° and 150°.

The porous wall 33 can be between one-eighth and one-half inch in thickness. Porous stainless steel has been found to be the best material for this wall except when hydrates are to be separated. When hydrates are to be separated, perforated or finned plates can be used for the wall material.

The velocity of the gas from nozzle 9 must be greater than Mach 1, and preferably between Mach 1.5 and Mach 2. The pressure of the gas applied to the separator assembly from pipe 1 should be greater than 300 psi. When an electric field is found desirable, the pressure must be great enough to permit a field strength of at least 50 kv per centimeter across the supersonic stream. The term "adiabatic efficiency", as used above, means the per cent of enthalpy change at a given expansion as compared to the enthalpy change for an isentropic expansion. In other words, the actual enthalpy drop is a certain per cent of the isentropic enthalpy drop with the final pressure held constant. In the nozzle block, the adiabatic efficiency should be as near as possible 100%. Manifestly, measuring at various points down the flow channel after the nozzle 9, the adiabatic efficiency will be substantially lower. The adiabatic efficiency after expansion in the droplet coalescing section 11 should not be less than about 50%.

In Fig. 4 there is shown a modification of the apparatus of Fig. 1 for use when it is desired to propagate sound waves of a particular frequency into the droplet-coalescing section. A pipe 61 having a whistle opening 65 is passed through an opening in the wall of nozzle housing section 5 so that the whistle opening 65 is in the cavity 3. A parabolic or curved sound reflecting surface 63 is placed so as to direct sound into the droplet coalescing section 11. A source of very high pressure gas, which can be a pump connected to line 95 to increase the pressure of the gas from line 95 to a pressure greater than the gas pressure at the outlet of pipe 1, is connected to line 61. Thus, gas passing through whistle opening 65 will produce a sound which is determined by the pressure on line 61 and the dimensions of the opening 65.

WHAT WE CLAIM IS:—

1. A method of separating components of a multicomponent gaseous stream which comprises submitting the multicomponent gaseous stream at high pressure to expansion whereby the gaseous stream acquires supersonic velocity and the temperature decreases so that the components of relatively high condensation temperature are liquefied in the form of droplets, and conducting the gas stream and entrained droplets through a curved passageway bounded on one side by a porous wall whereby, owing to centrifugal action, the liquid droplets are ejected from the gas stream to the porous wall and the liquid passes through the porous wall.

2. The method as claimed in claim 1 wherein the gaseous stream at high pressure is expanded through a nozzle and a divergent channel

3. The method of claim 1 or claim 2 wherein sound waves are propogated into the gaseous stream immediately prior to submitting it to expansion.

4. The method of any of claims 1 to 3 wherein the liquid flowing through the porous wall is additionally passed through a heat exchanger with, but separated from, said multicomponent gaseous stream to lower the temperature of said multicomponent gaseous stream.

5. The method of any of claims 1 to 4 wherein the non-condensed portion of said expanded gaseous stream is compressed to reduce the velocity thereof to less than supersonic.

6. The method a claimed in claim 5 wherein the gaseous fluid is initially expanded by reducing the pressure substantially isentropically and wherein the non-condensed portion of the expanded fluid is subsequently compressed by increasing the pressure substantially isentropically.

7. The method of any of claims 1 to 6 wherein the expanded fluid is subjected to an electrical field of at least 50 kilovolts per centimeter to coalesce liquid droplets therein before the direction of flow of the expanded fluid is changed.

8. The method of any of claims 1 to 7 wherein liquid is continuously withdrawn from the porous wall on the side thereof opposite said flow stream and regulating the pressure on said side of the porous wall opposite said flow stream to optimize the liquid content of fluids passing through said barrier.

9. The method of any of claims 1 to 8 wherein the barrier is a porous metal.

10. The method of any of the preceding claims wherein the stream is expanded with an adiabatic efficiency of at least 50%.

11. Apparatus for separating from a predominantly gaseous stream one or more components which condense above a given temperature from components which condense below a given temperature, comprising a means for substantially isentropically expanding said gaseous stream at high adiabatic efficiency to produce flow at supersonic velocity to reduce the temperature of the stream to below said given temperature; a means for introducing the expanded gaseous stream through a curved passageway bounded on one side by a porous wall, means for collecting the condensate flowing through said porous wall, means for regulating the back pressure on the side of said porous wall opposite said gaseous stream; and means for substantially isentropically compressing the uncondensed gaseous stream to reduce its flow velocity to subsonic.

12. The apparatus of claim 11 wherein there is included means for subjecting the supersonic stream to a high intensity electrical field.

13. The apparatus of claim 11 wherein means are provided for producing a sound wave of predetermined frequency content in the stream upstream of the electrical field.

14. The apparatus of any of claims 11, 12 or 13 wherein there is provided means for continuously removing liquids from the porous wall on the side thereof opposite the flow stream.

15. The apparatus of any of claims 11, 12, 13 or 14 further including means for continuously injecting liquid droplets into said flow stream upstream of said nozzle means.

16. The apparatus of claim 12 wherein the electric field has a potential gradient of at least 50 kilovolts per centimeter.

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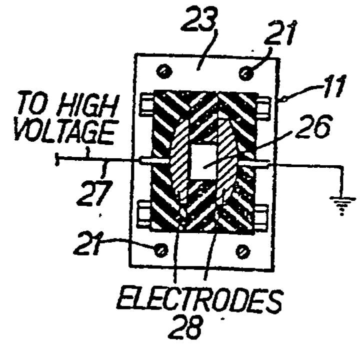
Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1968
Published at The Patent Office, 25 Southampton Buildings, London, W.C.2,
from which copies may be obtained.

FIG. 2.


23
21
11
TO HIGH VOLTAGE
26
27
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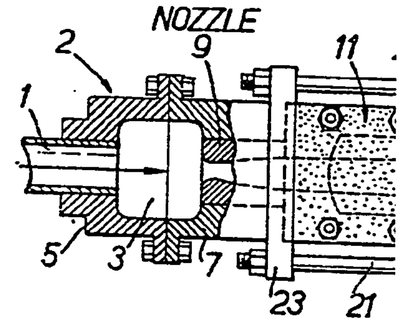
ELECTRODES
28


NOZZLE
2
9
11
1
5
3
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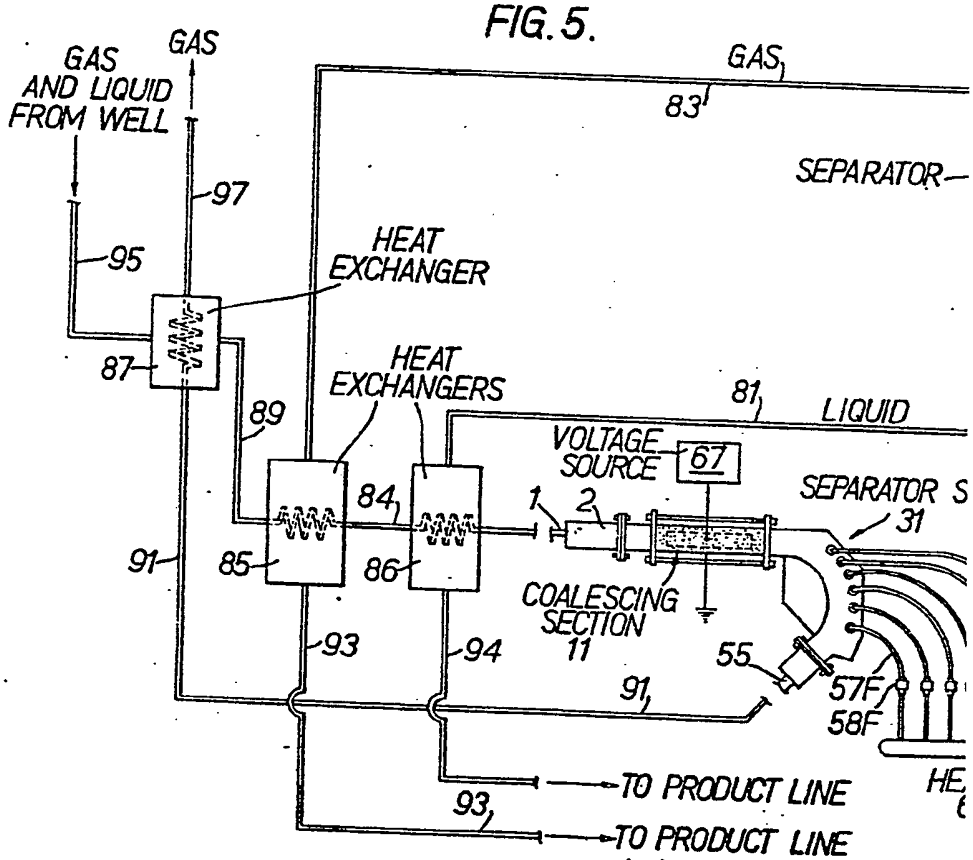
23
21

FIG. 5.


GAS AND LIQUID FROM WELL
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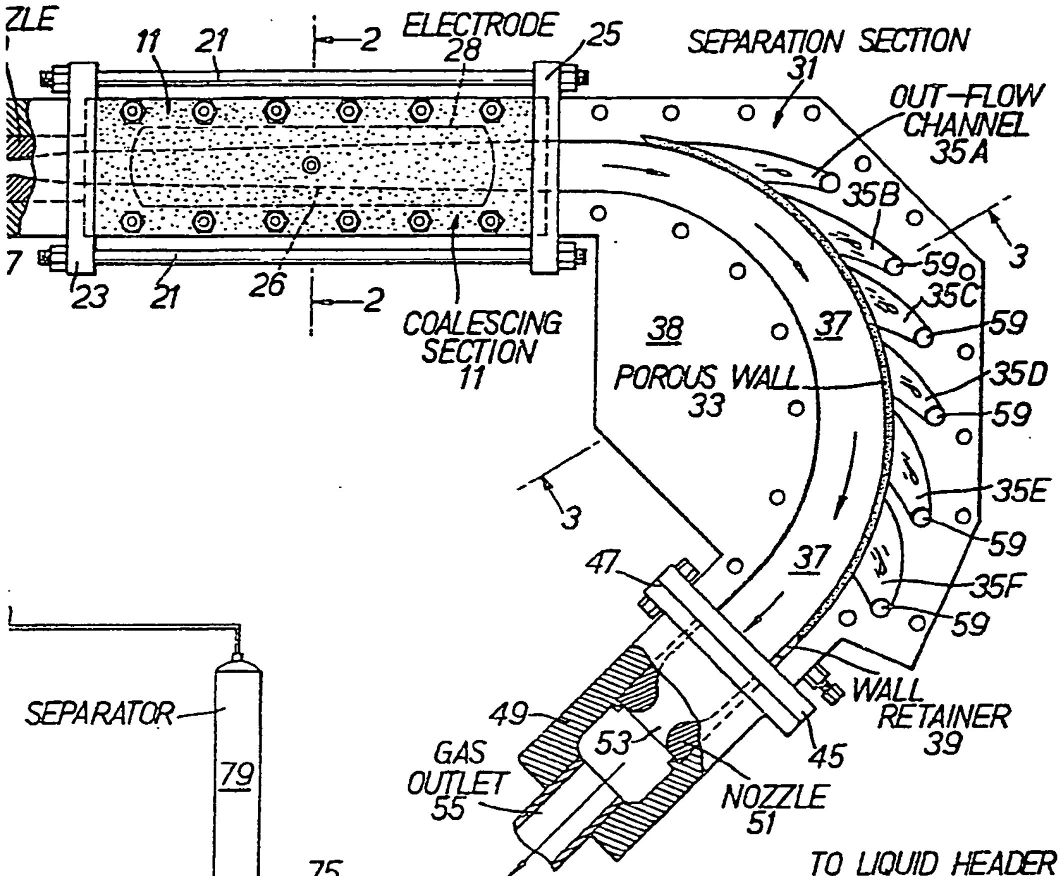
97
SEPARATOR
95
HEAT EXCHANGER
87
HEAT EXCHANGERS
89
81
LIQUID
VOLTAGE SOURCE
67
SEPARATOR S
31
84
1
2
91
85
86
COALESCING SECTION
11
93
94
55
57F
58F
91
TO PRODUCT LINE
93
TO PRODUCT LINE

1103130 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG. 1.



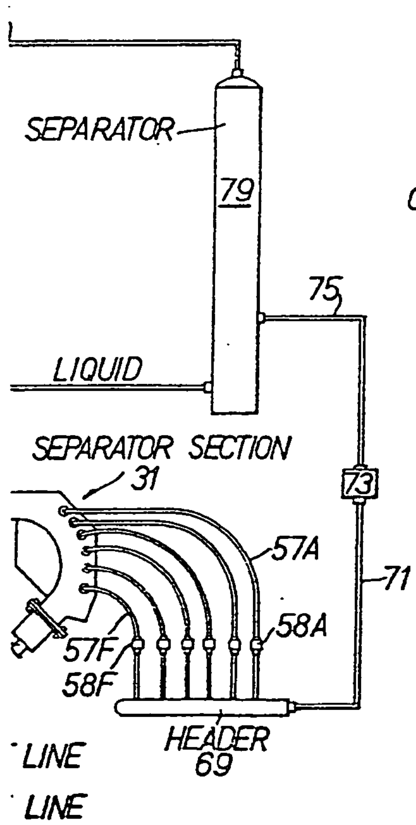




FIG. 3.

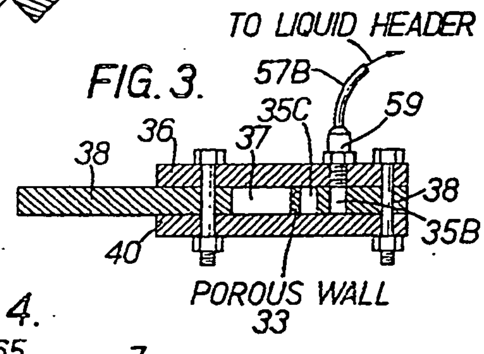
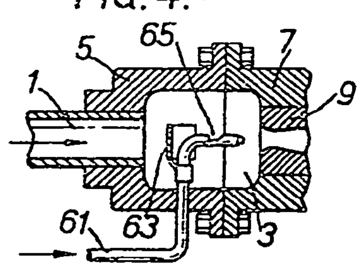



FIG. 4.



1103130 COMPLETE SPECIFICATION

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FIG. 1.

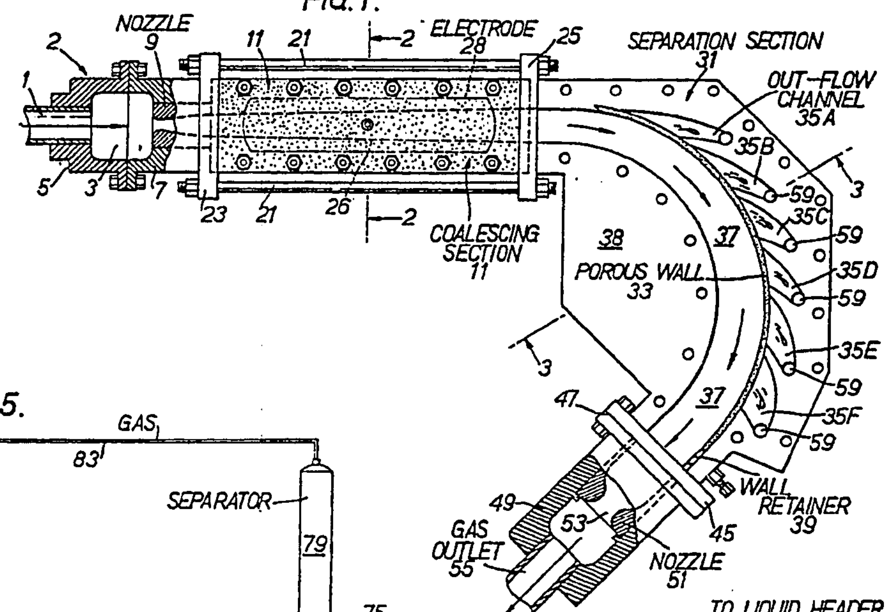


FIG. 2.

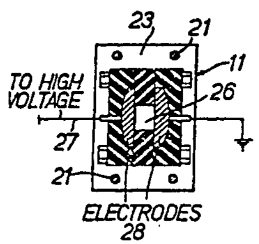


FIG. 5.

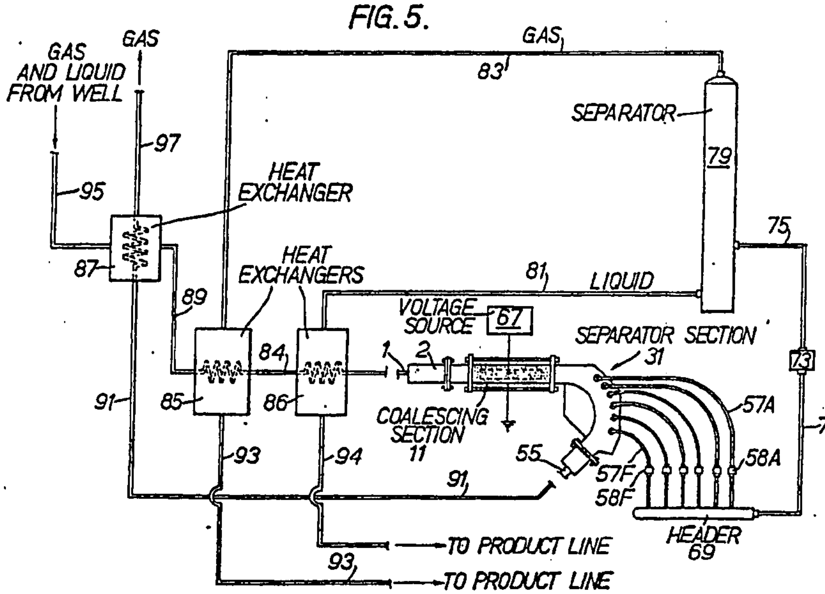


FIG. 3.

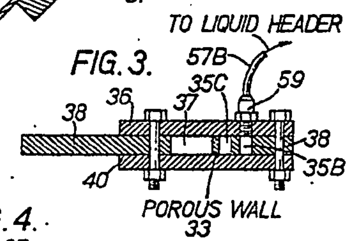


FIG. 4.